The Role of Modeling and Simulation in the Global Nuclear Energy Partnership

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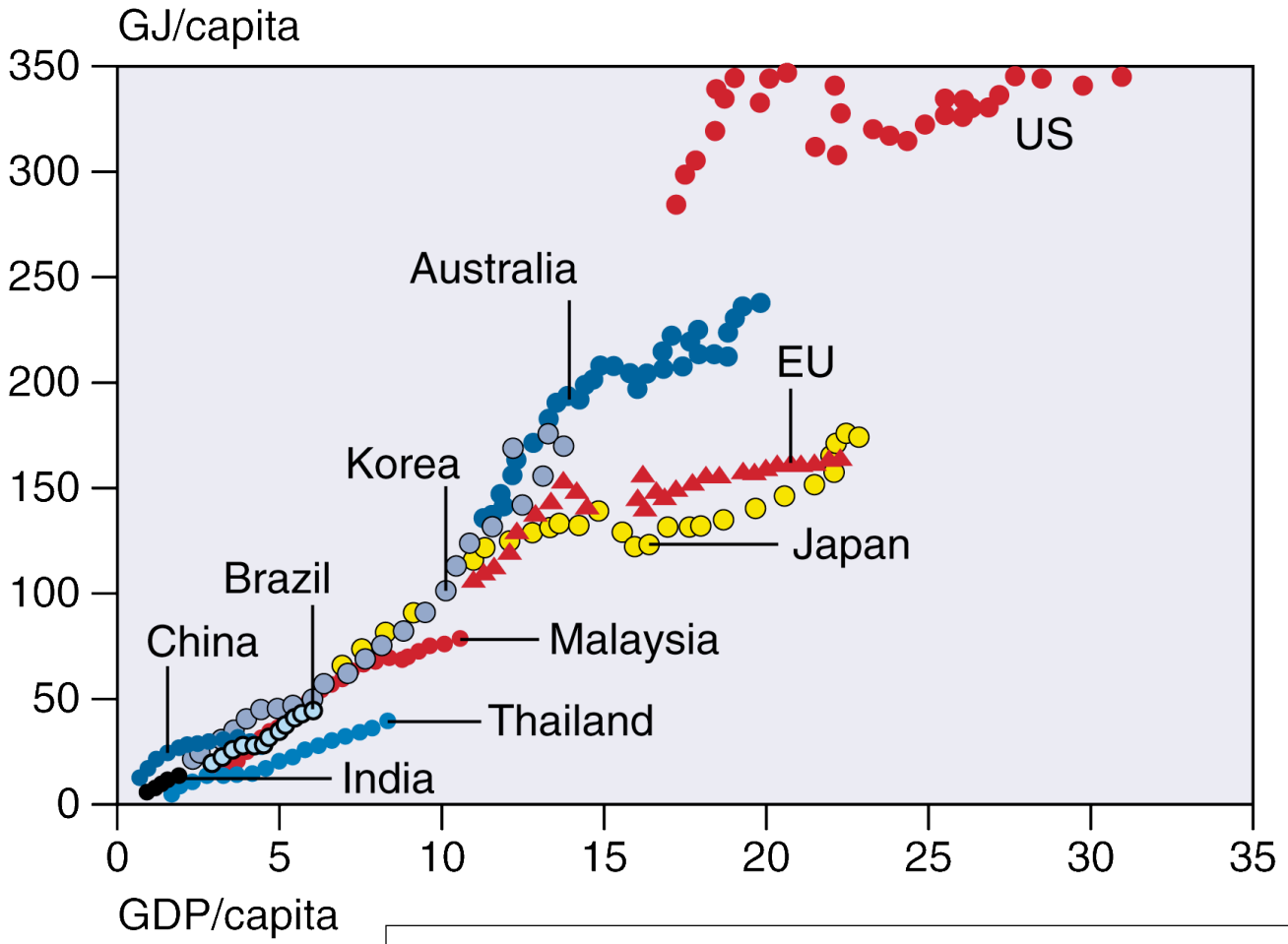
Outline

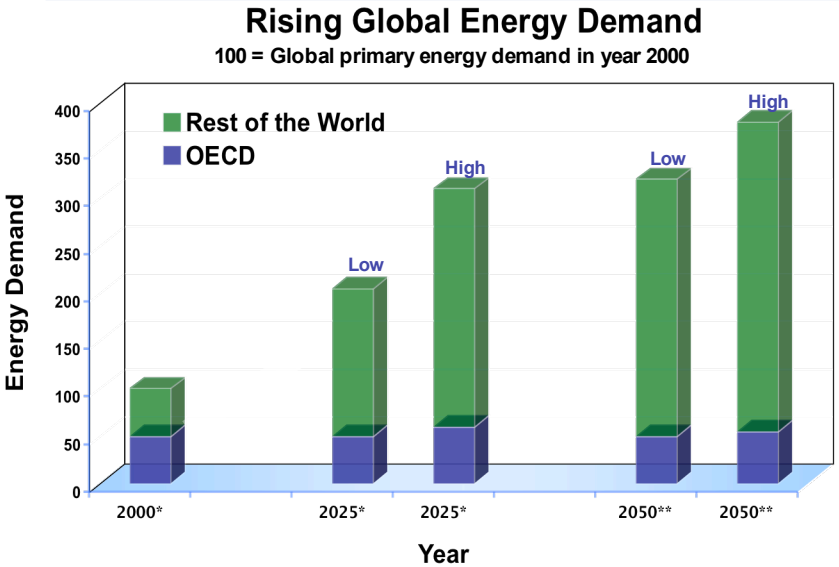
- What is GNEP and Why is it Needed?
- GNEP Path Forward
- The Role of Modeling and Simulation in GNEP

Energy is the Fuel of National Prosperity



Source: Royal Dutch Shell, "Exploring the Future - Energy Needs, Choices and Possibilities"

The Amount of Energy the World Will Need in this Century is Enormous



*Source: Shell Global Scenarios 2004
** Source: Shell Long-Term Energy Scenarios 2001

- Demand for energy and electricity to grow by 50% by 2030
- By 2030, developing countries energy usage will pass the industrialized countries

- Uncertainty of supply and price of natural gas and volatility of oil
- Challenge of lowering greenhouse gas emissions and mitigating global warming

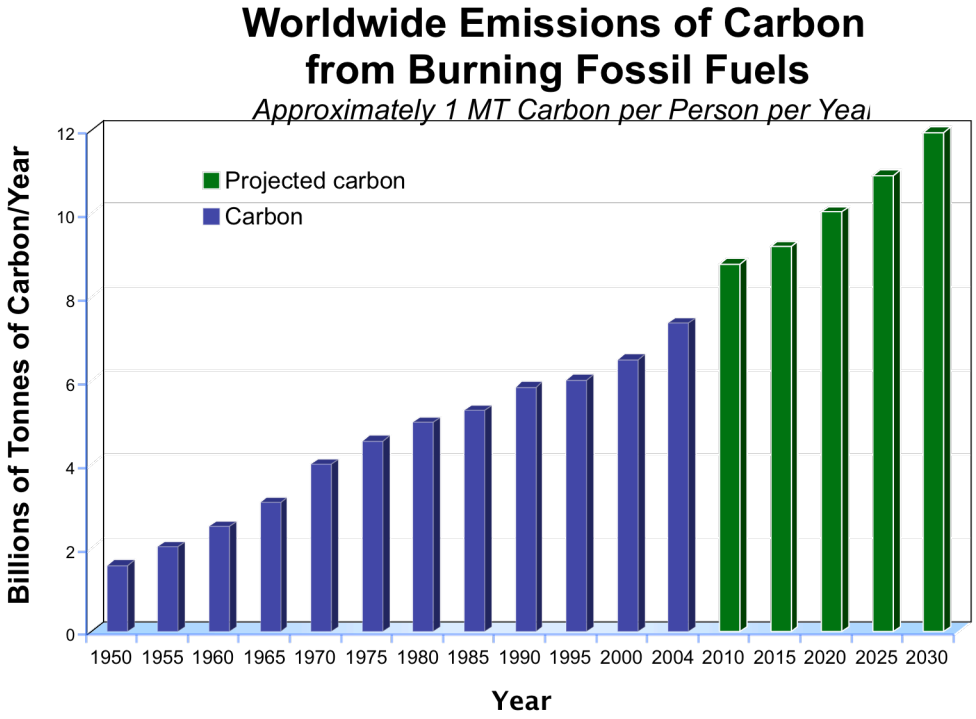


Table H-1, International Energy Annul 2004, EIA; Table A-10 International Energy Outlook 2006, EIA

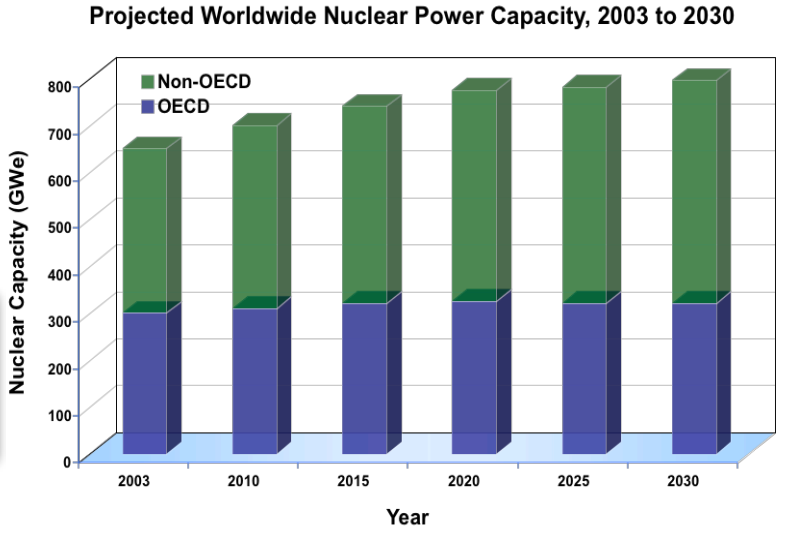
Changing energy landscape is causing the U.S. and other countries to seek sustainable energy, including expanded use of nuclear energy

Laboratory

As Nuclear Power Expands to More Countries, Will They Seek Complete Fuel Cycles?

- World nuclear energy is slated for a 50% increase over the next 15 years
- 30 plants under construction and 60 new plants expected on line over next 15 years
- Significant growth underway in Asia-Pacific region (Japan, China, Korea, India)
- In the last year, a host of countries have signed major nuclear deals, amounting to billions of dollars

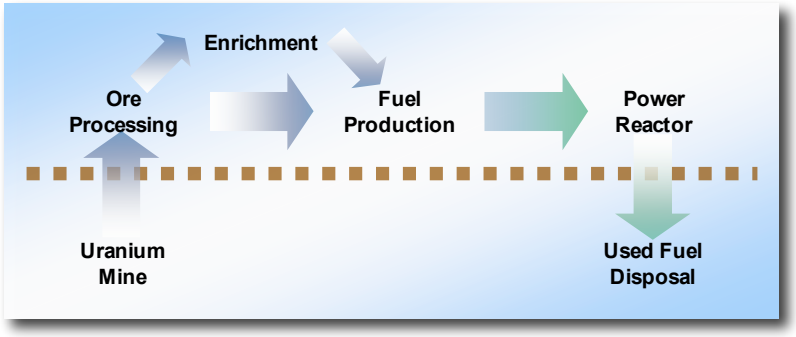
It is a vital interest of the U.S. that nuclear energy expand safely and securely

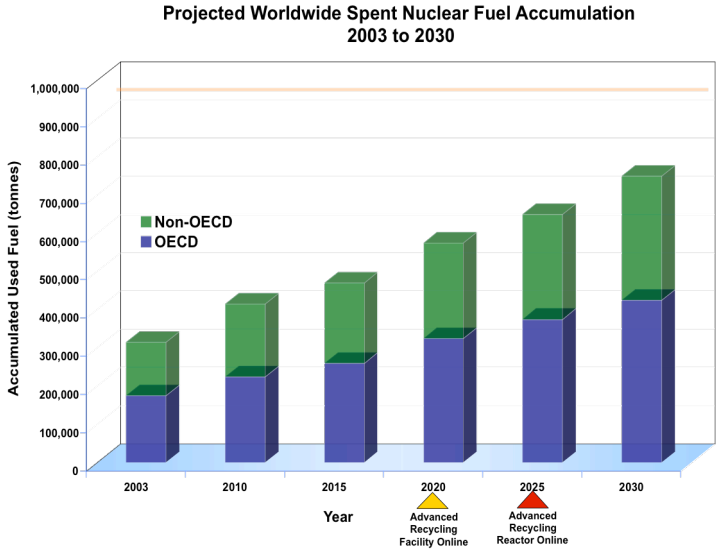


Countries with nuclear capacity will expand from 31 to 39.
The eight new countries will be Egypt, Indonesia, Iran, Israel, Kazakhstan, N. Korea, Turkey, Vietnam

Future of the Nuclear Fuel Cycle

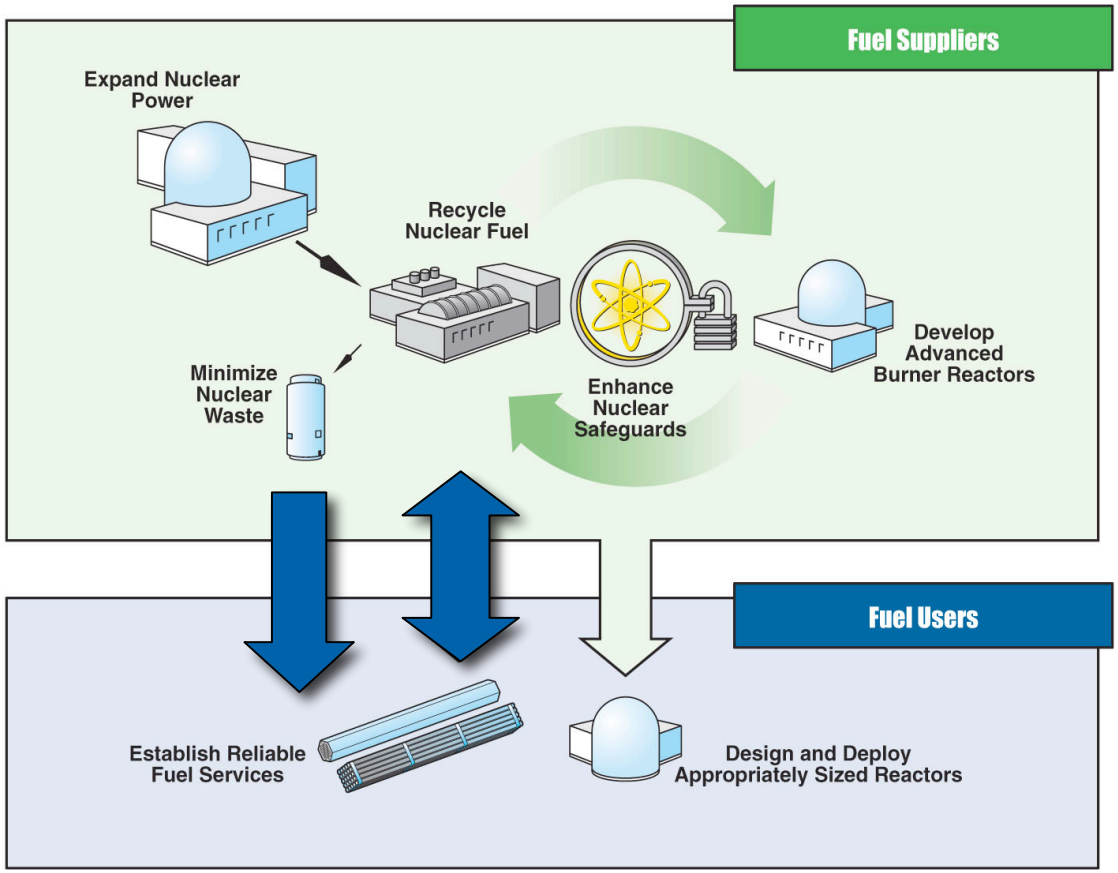
- **As nuclear expands, a greater number of states will consider developing their own fuel cycle facilities**
  - Reliable fuel services reduce number of states developing enrichment and reprocessing
- **Nuclear waste will become a major issue for global expansion of nuclear energy**
  - Recycling reduces long-term environmental burden and draws down stocks of civilian plutonium
- **In the longer-term future, uranium resources could be strained**
  - Recycling stretches energy resources





New international framework and advanced recycling technologies needed to ensure that nuclear energy expands safely and securely

Internationalizing the Nuclear Fuel Cycle



- **Fuel Suppliers:** operate reactors and fuel cycle facilities, including fast reactors to transmute the actinides from spent fuel into less toxic materials
- **Fuel Users:** operate reactors, lease and return fuel
- **IAEA:** provide safeguards and fuel assurances, backed up with a reserve of nuclear fuel for states that do not pursue enrichment and reprocessing

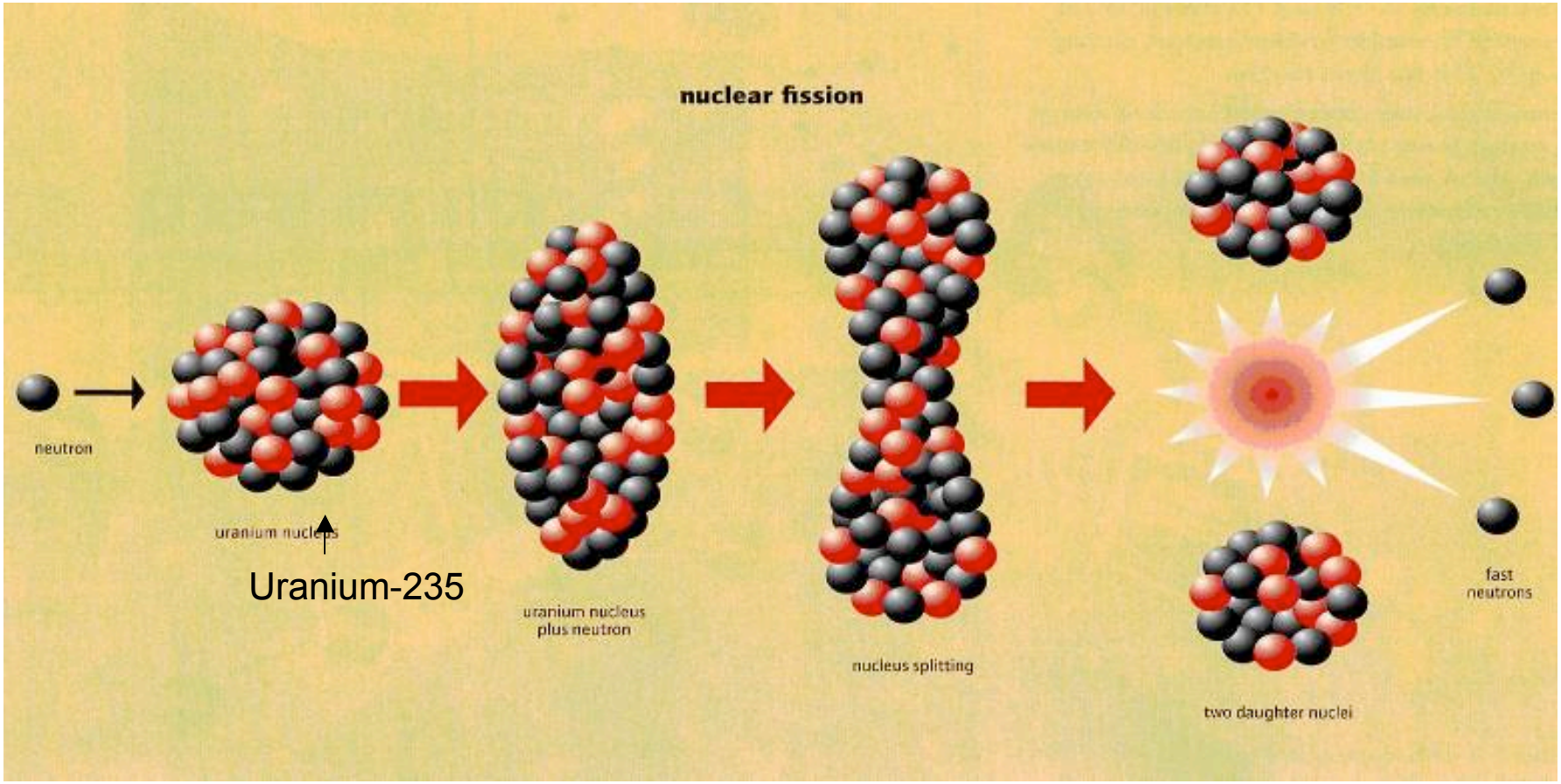
This approach makes diversion and misuse of fissile materials more difficult, more costly, and acquisition of sensitive fuel cycle technologies more difficult to justify as part of a peaceful nuclear program

Global Nuclear Energy Partnership — Nonproliferation Goals

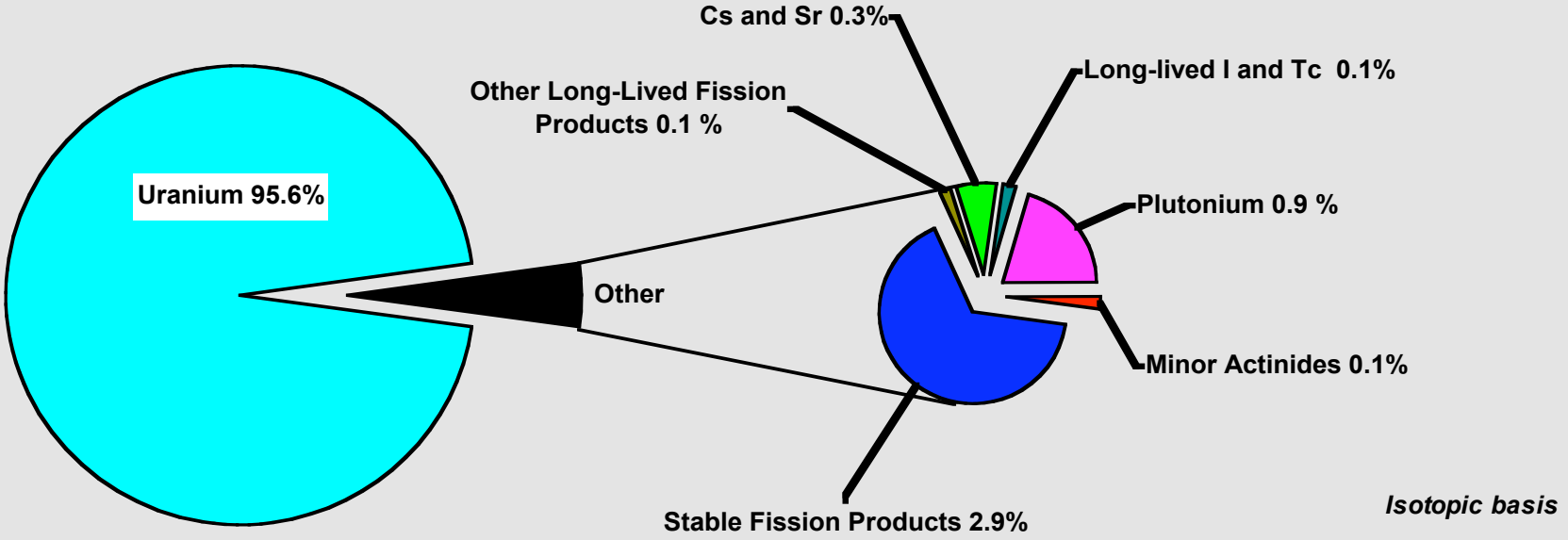
- **GNEP advances U.S. policy of discouraging separated plutonium and aims to reduce this risk by pursuing used fuel recycling that does not produce separated plutonium**
  - Discourage spread of enrichment and reprocessing capabilities
  - Minimize any further buildup of plutonium and eventually draw down existing stockpiles
  - Improve proliferation resistance of recycling technologies
  - Develop and incorporate advanced safeguards for GNEP technologies and more broadly

U.S. will work with domestic and international industry to prove the recycling technologies needed to close the fuel cycle, minimize waste, and obtain more energy benefits

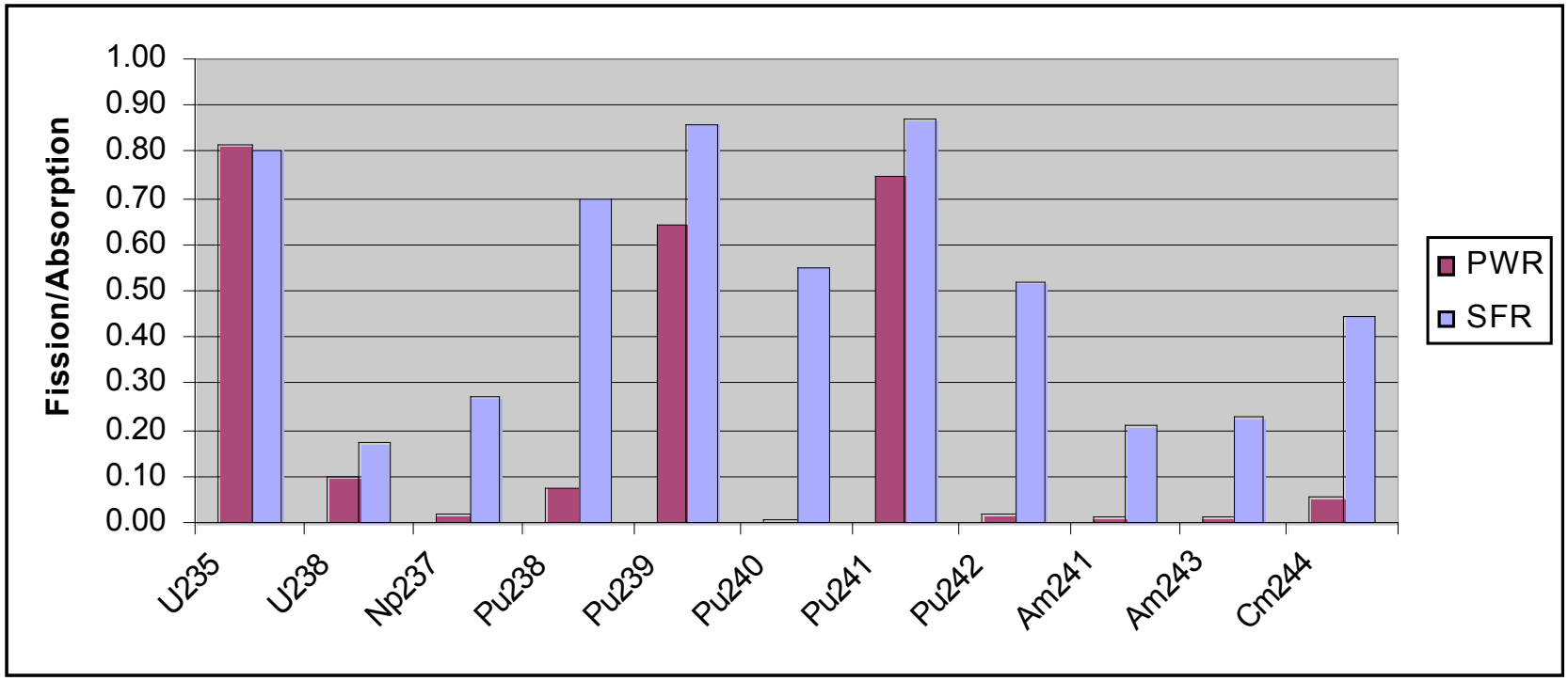
Nuclear Fission



Spent Nuclear Fuel (less cladding)



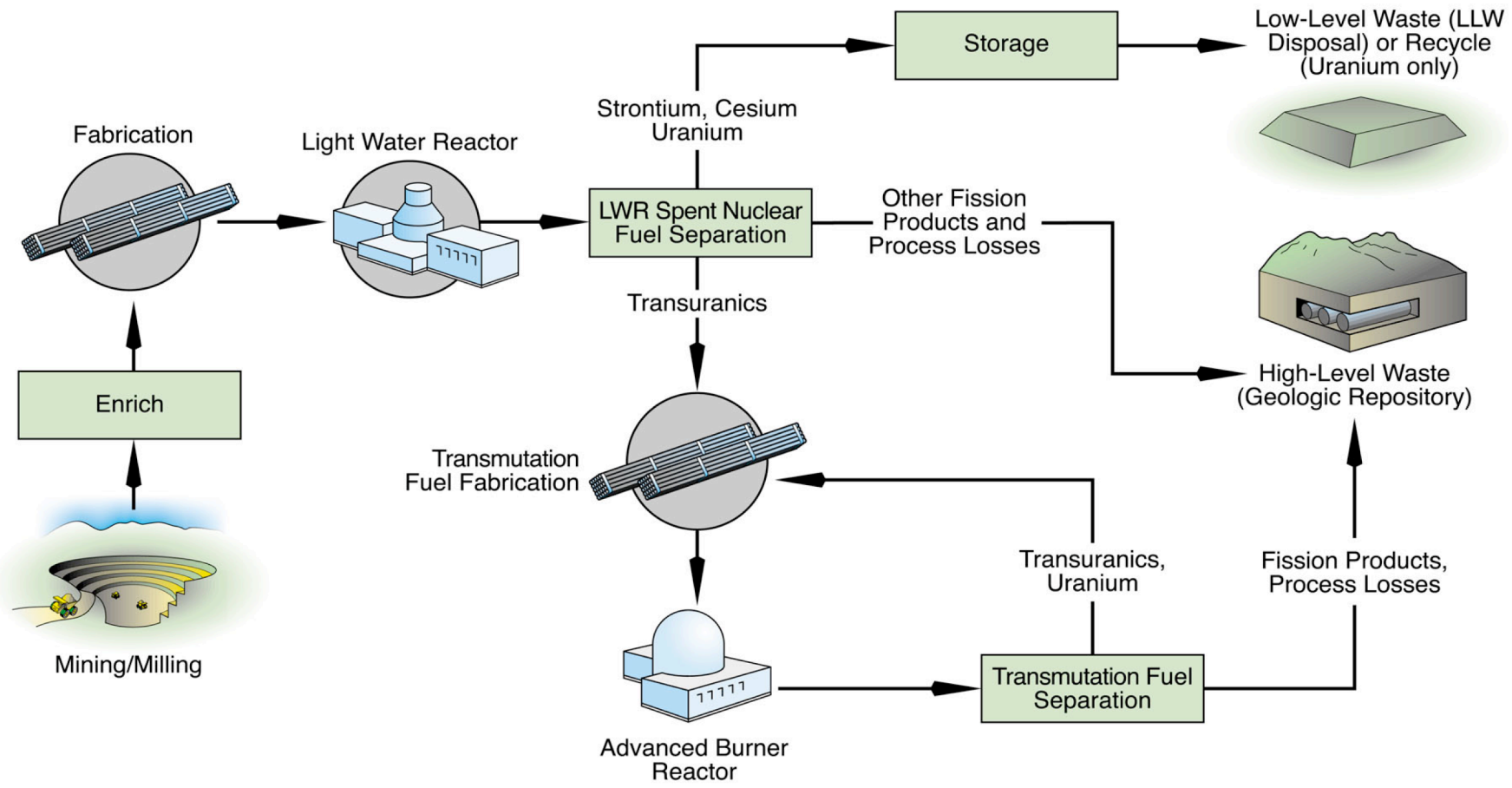
Physics of Advanced Reactors – Fission-to-Absorption Ratio for PWR and SFR



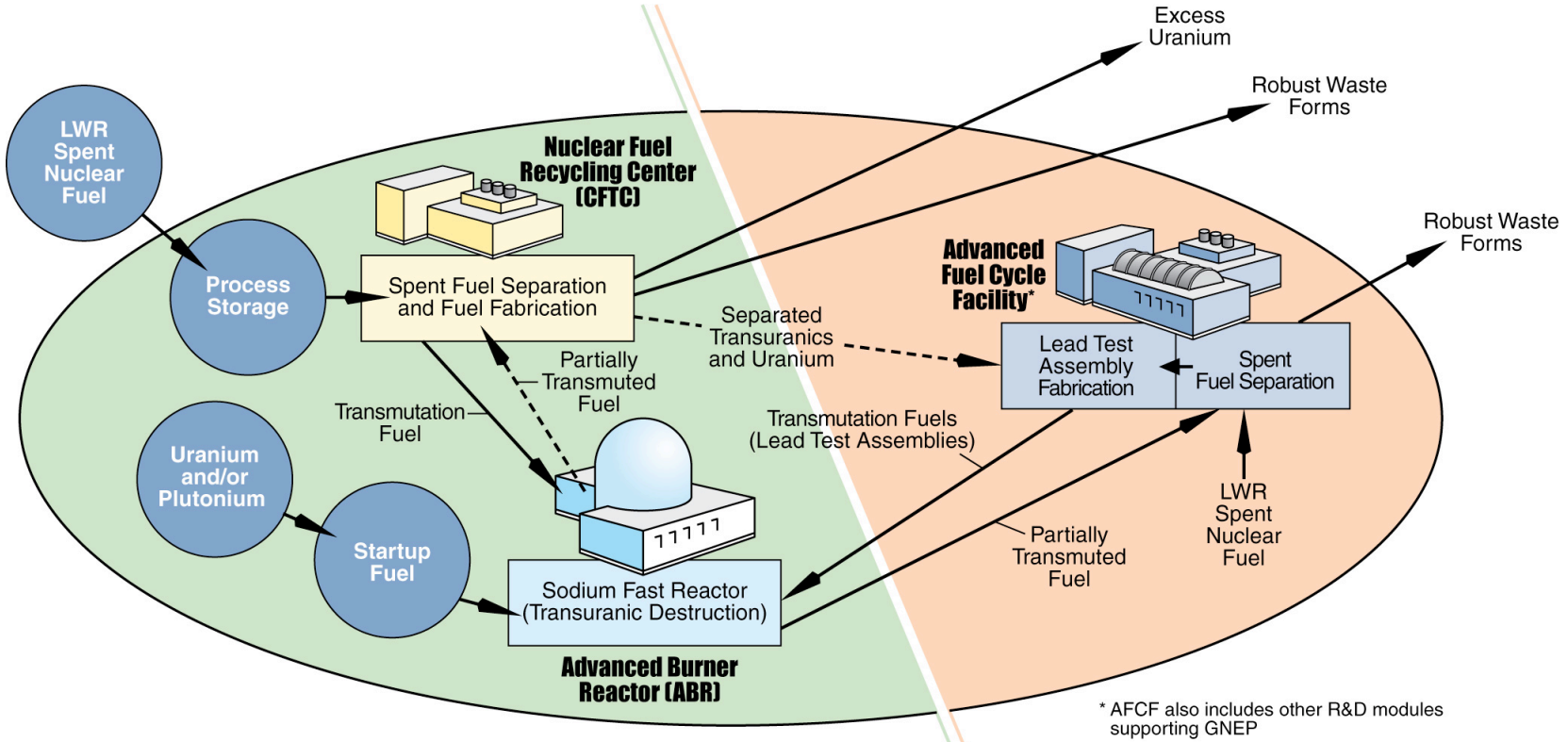
- **Fissile isotopes are likely to fission in both thermal/fast spectrum**
  - Fission fraction is higher in fast spectrum
- **Significant (up to 50%) fission of fertile isotopes in fast spectrum**

Net result is more excess neutrons and less higher actinide generation in FR

The Nuclear Fuel Cycle of the Future



The First GNEP Facilities

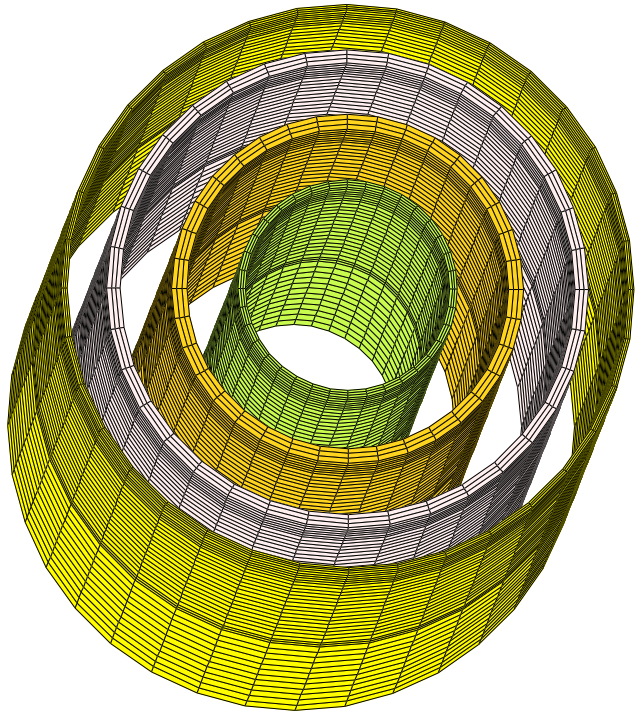


Industry-Led | **DOE Lab-Led**

(R&D and Technology Development)

Modeling and Simulation is an Essential Part of GNEP

- Computer simulation has significant potential to reduce overall costs in all aspects of nuclear plant design and operation
- For most of the technologies related to the three major GNEP facilities, testing is an extremely expensive, protracted, and in some cases unfeasible process
- Complementing or replacing testing with high-fidelity computer simulation will make it possible to understand fundamental processes that affect facility efficiency, safety, and cost



Status of Modeling and Simulation in the Nuclear Industry

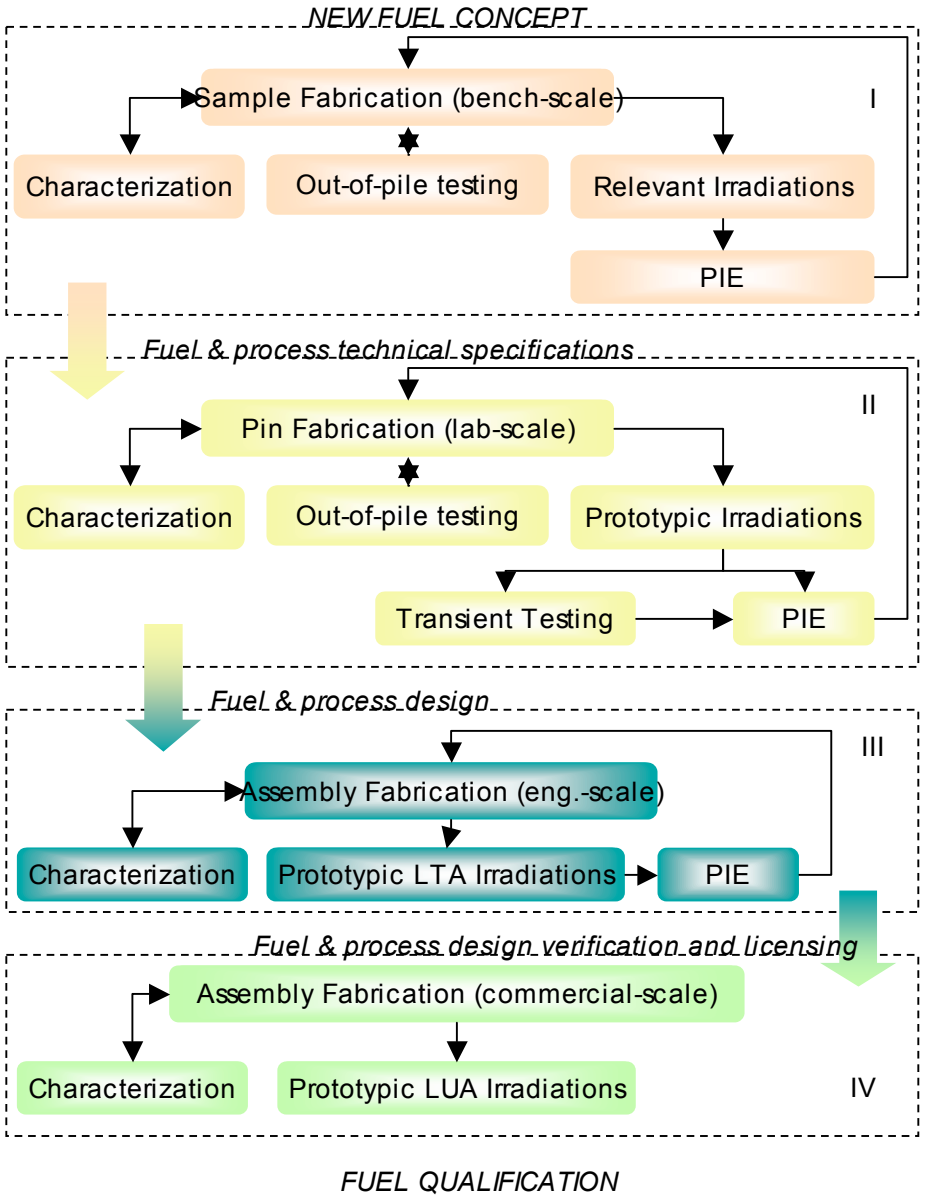
- In most cases, present simulation codes have been developed separately, and often independently, by industry and by R&D organizations
- Industry codes are often heavily dependent on validation (using proprietary experiments to define margins and bias factors); algorithms are tuned to specific needs
- R&D code development mostly stopped ~twenty years ago, with few exceptions.
- Many new advances in modeling and simulation are not yet taken into account
- A new effort in simulation is essential to develop an integrated approach

Reducing Uncertainty is the Ultimate Goal

- **There are two main source of uncertainties: input data, and modeling**
  - Example of input physical data: cross sections, physical characteristics of materials
  - Modeling uncertainties: coming from approximations made in the computational methodology used in the design process
- **Advanced simulation can provide a major benefit by reducing the impact of uncertainties coming from the modeling of the physical processes**
- **A scientific based approach will allow a reliable propagation of uncertainties and an accurate evaluation of the impact of the uncertainty coming from the input data.**

A team effort between science and engineering is needed for success

- Engineers will develop the specifications for the technology development and facilities
- Scientists will use first-principles methods to increase the accuracy of the modeling and simulation (and experiments which will provide validation data)
- A partnership, throughout this process, is needed between engineers and scientists to realize success



Example: Modeling and Simulation will benefit fuel development

- **New fuels are currently developed empirically**
- **Fuel performance codes are used to justify irradiation tests - not to design fuels**
- **Modeling and simulation is not going to replace the development process any-time soon (for at least another two decades)**
- **BUT, modeling and simulation can be used to streamline the process**
  - Faster and cheaper development of new fuel types
- **The proposed transmutation fuels are even more complex than the traditional fuel**

Summary

- **Global expansion of nuclear energy has begun**
- **Moving to a closed fuel cycle is a natural evolution and is necessary**
  - France, Japan, Russia all intend to deploy advanced recycling technologies
  - Better utilization of our uranium resources
  - Reduces proliferation risk
  - Reduces long-term environmental burden from nuclear waste
- **Once the GNEP fuel cycle becomes the norm, it will reduce the credibility of a country's need for its own enrichment or reprocessing capability for peaceful purposes.**
- **Modeling and simulation will play an essential role in the development of the Global Nuclear Energy Partnership**

Nuclear Energy will contribute to a more secure and prosperous tomorrow